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the OSHA benzene

PRELIMINARY ACTION PLAN
FOR COMPLIANCE WITH THE
OSHA BENZENE STANDARD

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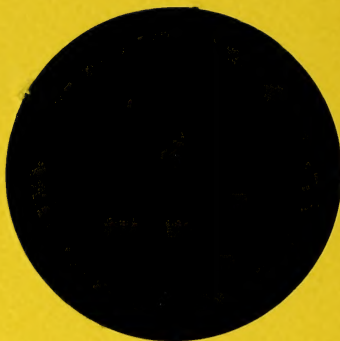
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PRELIMINARY ACTION PLAN
FOR COMPLIANCE WITH THE
OSHA BENZENE STANDARD


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INTRODUCTION

This report discusses MERDI's plan for complying with the OSHA Benzene Standard during the operation of the Component Development and Integration Facility (CDIF) located in Butte, Montana. The U.S. Department of Health, Education, and Welfare has stated that "The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards at their workplace. To provide relevant data from which valid criteria and effective standards can be deduced, the National Institute for Occupational Safety and Health (NIOSH) has projected a formal system of research, with priorities determined on the basis of specified indices.

"It is intended to present successive reports as research and epidemiologic studies are completed and sampling and analytical methods are developed. Criteria and standards will be reviewed periodically to ensure continuing protection of the worker."¹

Benzene has been identified as a potential problem during CDIF operation (the Component Development and Integration Facility--first stage of the national magnetohydrodynamics program). Benzene has long been recognized as a toxic substance capable of causing acute and chronic health effects. More recently, a determination by the Occupational Safety and Health Administration (OSHA), based on available scientific evidence, has established that employee exposure to benzene presents a cancer hazard--specifically the hazard of developing leukemia.² Therefore, in accordance with OSHA's regulatory approach to the control of employee exposure to carcinogens, a standard was established to limit employee exposure to benzene to the lowest feasible level. The standard prescribes limits of one part benzene per million parts of air (1 ppm) as an eight-hour time-weighted average concentration, with a ceiling level of 5 ppm for any 15-minute period during the eight-hour day. Limits on eye and skin contact with benzene also are defined.

The new standard outlined in 29 CFR 1910.1028 has been determined by OSHA to be more effective than the previous corresponding standards and therefore supersedes those previous standards. However,³ standards not specifically mentioned in 29 CFR 1910.1028 still apply.

I. ORGANIZATION OF EFFORTS

MERDI will develop a program for use at the CDIF to meet the requirements of the Occupational Safety and Health Administration (OSHA) benzene standard. The following steps will be taken to ensure a coordinated and comprehensive program.

- A. A program coordinator will be appointed to oversee the program and preside over meetings of a committee consisting of representatives of the personnel division, safety, medical, and industrial hygiene staff (if available), project leaders, facilities staff, etc. Representatives from employee organizations may be included also.⁴
- B. All personnel entering a CDIF operational area determined to be benzene hazardous will comply with the appropriate provisions of this action plan. MERDI/CDIF will retain sole authority to ensure this compliance.
- C. Areas in which benzene is used or may be released will be identified. The CDIF and supporting analytical laboratories will be monitored. Possible areas of concern include the following:

1. CDIF

- a. Coal drying (benzene has been identified in the off-gases of the drying process),
- b. Oil and coal handling and storage,
- c. Sampling personnel,
- d. Part-time CDIF or other MERDI personnel who visit CDIF on a regular basis, and
- e. Facility staff.

2. Laboratories

- a. Use of benzene for organic soluble fraction determination, and
- b. Solvent storage

Should there be questions regarding potential sources of exposure to benzene, assistance will be provided by the Environmental Activities Staff, Program Control and Support Division, U.S. Department of Energy (DOE).

- D. An assessment of resources and capabilities for the environmental monitoring, clinical medical surveillance, employee education, and record maintenance will be made. The Environmental Activities Staff, Program Control and Support Division, DOE, will be advised if any assistance is needed.⁴

II. ENVIRONMENTAL APPRAISAL, DESIGNATION OF ACTION LEVEL IN REGULATED AREAS, AND PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS

The requirement for MERDI/CDIF to comply with the benzene standard is governed by the following statement. "The benzene standard, in its final form, will require all industries that produce or use benzene, petrochemicals, products, and services involving the use of solvents derived from petroleum as well as the production of crude and refined petroleum products, to undertake an initial determination of the extent to which their employees are exposed to benzene."⁵ The results of the initial exposure measurements will determine the types of precautions MERDI/CDIF will be required to take to comply with the provisions of the standard. The MERDI/CDIF program is outlined below.

- A. Preliminary evaluations will be conducted by environmental monitoring of the CDIF and at supporting analytical laboratories. A charcoal tube collection method will be used for benzene collection, as approved by the National Institute for Occupational Safety and Health (NIOSH). The minimum requirement for sampling a preliminary evaluation process consists of five short-term grab samples averaged over an eight-hour period (see Appendix I). Samples will be analyzed by the gas chromatography method outlined in the NIOSH Manual of Analytical Methods⁴ (see Appendix II). Local collection and laboratory facilities are adequate for analysis.

Benzene concentrations will be categorized in one of three levels: below the action level; above the action level but below the permissible exposure level (PEL); or above the PEL. The action level is defined as a benzene exposure equal to one-half of the PEL.

For areas determined to have initial monitoring measurements below the 0.5 ppm action level, no further monitoring will be necessary until a redetermination is required as a result of a process, control, or personnel change. (For further details, see the Federal Register, Volume 43, No. 29, Friday, Part II, p. 5951, February 10, 1978.) Employees in such areas will not have to be monitored periodically nor will MERDI/CDIF be required to provide medical surveillance. MERDI/CDIF, however, will train these employees, label benzene products, provide protective clothing where necessary, and retain a record of the initial employee examination and re-examination (if required).

Areas found in excess of the benzene action level but below the PEL require further monitoring and medical surveillance. The medical surveillance will be provided quarterly to one-sixth of the potentially exposed employees. Methods of compliance and respiratory protection do not apply in these areas, but MERDI/CDIF will comply with all other requirements of the standard.

Employees working in areas in excess of the PEL (1 ppm) will be monitored monthly. All provisions of the standard will apply in this case.

Should the levels of exposure change, the following procedures have been adopted to allow compliance level reclassification. MERDI/CDIF will "discontinue monitoring those employees for whom two consecutive measurements taken seven days apart show exposures to be below the



action level. Where employee exposure measurements fall below the permissible exposure limit but are at or above the action level, the employer may alter the monitoring schedule for those employees from monthly to quarterly after two consecutive measurements taken seven days apart indicate a reduction in levels."⁶

All employees who work in areas where benzene may be present will be notified within five days after the monitoring is completed.

- B. "For each location in which findings indicate benzene exposures in excess of the PEL, MERDI/CDIF will provide immediate personal protective equipment (NIOSH approved) until a process evaluation can be undertaken. MERDI/CDIF also will comply with the following requirements from the Federal Register (February 10, 1978) concerning respirators.

1. Respirators will be selected from among those approved by NIOSH under 30 CFR Part 11 (see Appendix III).
2. MERDI/CDIF will provide the type of respirator affording the necessary amount of protection (see Appendix I).
3. MERDI/CDIF shall institute a respiratory program in accordance with 29 CFR 1910.134 (b), (d), (e), and (f) (see Appendix IV).
4. Cartridges of canisters will be changed at the end of their service life or the end of the shift in which they are initially used, whichever comes first.

"This evaluation will take into account the source of the benzene and the type of work being performed and the resulting nature or exposure, with a view toward developing feasible engineering and work practice controls. A written "compliance program" will be prepared and action initiated (engineering design, budget, etc.) to implement same."⁴ MERDI/CDIF "will institute engineering and work practice controls to reduce employee exposure to benzene...below the PEL, except to the extent that such controls are not feasible..Where feasible engineering controls and work practices are insufficient to reduce exposure to the permissible limits the employer [MERDI/CDIF] will use controls to reduce exposures to the lowest achievable level and then supplement by use of respiratory protection."⁷ MERDI/CDIF also will comply with the following requirements from the Federal Register (February 10, 1978) concerning respirators.

"The final standard requires that where the employee is exposed to eye contact or repeated skin contact with benzene (as is possible in the analytical laboratories), the employer must provide and assure that employees wear the appropriate protective clothing and equipment. This requirement compels employers to furnish, where necessary, such items as goggles, face shields, and gloves or footwear. MERDI/CDIF will determine the requirements necessary for protective clothing and equipment to prevent eye or skin contact. The required items will be available for use in regulated areas, and a personal equipment maintenance program will be established.

"In addition to the obligations to institute engineering and work practice controls, except to the extent that such controls are not feasible, the final standard also requires that each employer establish and implement a plan, including schedules for reducing exposures to within the permissible exposure limit or to the greatest extent feasible, solely by engineering and work practice controls."⁹ These written plans will be furnished by MERDI/CDIF upon request for examination and copying to representatives of the Assistant Secretary and the Director. These plans will be reviewed and updated periodically to reflect the current status of exposure control.

MERDI/CDIF will establish the required periodic environmental monitoring and associated time schedule. Administrative procedures will be established for notifying the individual responsible for safety or industrial hygiene when production or control changes create new or additional exposures to benzene; appropriate follow-up monitoring will be performed. Procedures for prompt monitoring and worker protection following spills, leaks, ruptures, or breakdowns will be developed. If workplace exposures are not reduced to below the action level, periodic remonitoring will be performed as specified.

- C. Access will be regulated to areas found in excess of the PEL. MERDI/CDIF will identify and control access to the regulated areas and will notify OSHA within 30 days following the establishment of such areas. "Required warning signs, 29 CFR 1910.1028 (k), (1), will be posted at the identified regulated areas within five days of designation. In addition, a copy of Appendices A and C of the standard will be posted at conspicuous locations at each required area. The necessary warning labels, CFR 1910.1028 (k) (4), will be placed on containers and vessels. A copy of Appendices A and C will be posted in supply and storage areas and workrooms where such containers of benzene are present."⁴
- D. A permanent central repository for information and records of the results of environmental monitoring will be established. Employees will be notified periodically of the location and access procedure to this information.

III. CLINICAL MEDICAL SURVEILLANCE

- A. MERDI/CDIF will establish a medical surveillance program in compliance with 29 CFR 1910.1028 (i) and will provide for the biological monitoring of the necessary employees (see Appendix V). "The medical surveillance program will consist of three main elements: 1) an initial and periodic examination for all employees exposed to airborne benzene concentrations at or above the action level; 2) evaluations of abnormal findings by a hematologist; and 3) a biological screen for workers who may have received excessive exposure to benzene as a result of an emergency."¹⁰ Both a medical work history and a series of laboratory blood tests are required in the initial examination. Specified elements for the history are "a history which includes past work exposures to benzene or any other hematologic toxins; a family history of blood dyscrasias including hematological neoplasms; a history of blood dyscrasias including genetically related hemoglobin alterations, bleeding abnormalities, abnormal function

of formed blood elements; a history of renal or liver dysfunction; a history of drugs routinely taken, alcoholic intake and systemic infections."¹¹ MERDI will include the following laboratory hematological tests as part of the initial examination, as detailed in the Federal Register (May 27, 1977).

1. Red Cell count,
2. White Cell count,
3. Hematocrit,
4. Hemoglobin,
5. MCV--(mean corpuscular volume),
6. MCH--(mean corpuscular hemoglobin), and
7. MCHC--(mean cell hemoglobin concentration).

A brief, updated history will be gathered semi-annually at the time of one of the periodic blood examinations. Should the initial, periodic, or emergency examination of an employee show abnormal test results, MERDI/CDIF will refer the employee to a hematologist for further evaluation if certain specified warning signs appear (1910.1028 Section 7).

"If a worker is exposed to a massive release of benzene, [MERDI/CDIF] will provide for each individual so exposed a urinary phenol assay at the end of the work shift in which the emergency occurred. If the results of such a test corrected to a specific gravity of 1.024 are less than 75 mg/l, no further tests will be performed. However, if a urinary phenol result is greater than 75 mg/l, indicating an average exposure above 10 ppm, then a complete blood count, including a differential count will be performed as soon as practicable [see Appendix V].

"If the red blood cell or platelet count or hemoglobin differ more than $\pm 15\%$ from the most recent prior exam's findings, the worker's test results will be referred to a hematologist for additional evaluation. Also, if the levels of the three formed elements lie outside of the prescribed ranges further evaluation by a hematologist will be required...

"For all medical examinations, the employer [MERDI/CDIF] will provide the physician with certain information. This information includes a copy of the regulation, a description of the affected employee's duties as they relate to the employee's exposure, the results of the employee's exposure measurement, if any, or the employee's anticipated or estimated exposure level, a description of any personal protective equipment used or to be used, and information from previous medical examinations of the affected employee to the extent that it is not readily available to the physician (1910.1028 Section 3)."¹²

MERDI/CDIF will "obtain a written opinion from the examining physician containing: the physician's opinion as to whether the employee has any detected medical conditions which would place the employee at an increased risk of material impairment of health from exposure to benzene, the results of the medical tests performed, and any recommended limitations upon the employee's exposure to benzene and upon the use of protective clothing and equipment such as respirators. This written opinion will not reveal specific findings or diagnoses unrelated to occupational exposure, and a copy of the opinion will be provided to the affected employee."¹²

- B. Employees working in areas where benzene may be present will be notified within five days after the completion and evaluation of the environmental monitoring. The following steps then will be taken for those employees whose exposure exceeds or may exceed the action level.
 - 1. Employees will be advised of the environmental findings and the details of the compliance plan in writing.
 - 2. An initial medical surveillance exam will be scheduled for employees.
 - 3. Employees will be provided with a copy of Appendices A and C of the OSHA standard (see Appendix I).
 - 4. Employees will be given specific information and training on the potential work hazards and necessary precautionary measures including proper use of protective equipment and other requirements detailed in the OSHA standard. This orientation will be completed as soon as practicable after employee notification.
 - 5. Employees will be provided a written copy of the findings upon completion of a physical examination. A copy of the physician's written findings will be included in the medical records folder. The physician will include the information called for in 29 CFR 1910.1028 (i) (4) (see Appendix V). Suitable written forms will be utilized by the physician.
 - 6. Employees will be rescheduled for examination at semi-annual increments.⁴
- C. The personnel director will receive copies of the physician's written findings for distribution to the employees. A review will be made with safety and industrial hygiene personnel on recommendations for limiting the employees' exposure to benzene, (e.g., use of respirators, etc.). Appropriate action will be taken with the individual employee's supervisor to ensure that any special requirements recommended by the physician are instituted and maintained.⁴
- D. A permanent clinical medical repository will be established as required in 1910.1028 (1) (2). Duplicate information will be placed in the employee's general medical record file and a system for identification of those files as being benzene-exposed personnel established. Medical records on benzene will be maintained by the director of personnel as

a special file with access restricted to employees and their designated representatives, authorized Department of Energy Occupational Health, Safety and Industrial Hygiene personnel, or those of the Department of Labor/OSHA. Employees will be notified periodically as required under 29 CFR 1920.1028.⁴

IV. SPECIAL PROCEDURES

- A. MERDI/CDIF will establish an employee training program as called for in 29 CFR 1910.1028 (j). Employees and supervisors working in areas where benzene may occur will receive bi-annual training. New employees who received orientation within the past year will be excused. A record of all such training will be maintained as part of the permanent files on benzene. These records will include the date the training was given, list of attendees, and a summary of subjects covered.²³ The information imparted to the employee will include the nature of benzene-related health problems, the necessity for exposure control, and the purposes of medical surveillance and respiratory protection. MERDI/CDIF will inform employees of the information in Appendices A and B (1910.1028) which details the signs and symptoms of benzene induced diseases and will supply copies of these appendices.
- MERDI/CDIF also will supply to the Assistant Secretary of Labor for OSHA and the Director of NIOSH upon request all materials related to the training program.
- B. MERDI/CDIF will post signs that clearly designate all work areas where benzene may be present, as detailed in 1910.1028 (k).
- C. MERDI/CDIF will maintain such records as are outlined in 1910.1028(l). Records will include information on exposure measurements and medical surveillance.
- D. MERDI/CDIF will provide an opportunity to affected employees or their designated representatives to observe any measuring or monitoring of employee exposure to benzene.¹³
- E. MERDI/CDIF will submit an appropriate report to the designated agencies within 30 days after completion of the initial actions called for by the benzene standard. The report will include the following information:
1. Number of regulated areas identified along with a description of the areas, number of employees, and copy of compliance plan (with estimates of the costs for compliance);
 2. The date physical examinations were completed;
 3. The date employee notifications were completed;
 4. The date the initial employee orientation has been completed; and
 5. Problems or difficulties encountered in the implementation of the standard.⁴

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APPENDIX I

Code of Federal Regulations for Benzene

Chapter XVII

Occupational Safety and Health Administration

Title 29--Labor



§ 1910.1028 BENZENE

(a) Scope and application. (1) This section applies to the production, reaction, release, packaging, repackaging, storage, transportation, handling, or use of benzene.

(2) This section does not apply: (i) To the storage, transportation, distribution, dispensing, or sale of gasoline as a fuel subsequent to discharge of such gasoline from bulk terminals; or (ii) where the exposure to benzene is only from liquid mixtures containing 1 percent or less of benzene by volume, or the vapors released from these liquids.

(b) Definitions. "Assistant Secretary" means the Assistant Secretary of Labor for Occupational Safety and Health, or designee.

"Benzene" (C₆H₆) (CAS Registry No. 000071432), means benzene, or a mixture of liquids containing benzene, or the benzene vapor released by these liquids.

"Bulk terminal" means a facility which is primarily used for the marketing of gasoline and which receives its petroleum products by tanker, barge, or pipeline.

"Director" means the Director, National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, or designee.

"OSHA Area Office" means the Area Office of the Occupational Safety and Health Administration having jurisdiction over the geographic area where the employer's establishment is located.

(c) Exposure limits--(1) Permissible airborne exposure limits. (i) The employer shall assure that no employee is exposed to an airborne concentration of benzene in excess of 1 part benzene per million parts of air (1 ppm), as an 8-hour time-weighted average.

(ii) The employer shall assure that no employee is exposed to an airborne concentration of benzene in excess of 5 ppm as averaged over any 15 minute period.

(2) Dermal and eye exposure limit. The employer shall assure that no employee is exposed to eye contact or repeated skin contact with benzene.

(d) Notification of use. Within 30 days of the effective date of this section, every employer who has a place of employment where benzene is present, shall report the following information to the nearest OSHA area office for each such establishment:

(1) The address and location of each establishment where employee exposure to benzene occurs;

(2) A brief description of each process or operation which may result in employee exposure to benzene;

(3) The number of employees engaged in each process or operation which may result in exposure to benzene and an estimate of the frequency and degree of exposure that results; and

(4) A brief description of the employee safety and health program as it relates to limitation of employee exposure to benzene.

(e) Exposure monitoring and measurement--(1) Initial monitoring.

(i) Each employer who has a place of employment where benzene is present, shall monitor each such workplace and work operation to determine the airborne concentrations of benzene to which employees may be exposed. This determination shall be made by monitoring and measurements which are representative of each employee's exposure to benzene over an 8-hour period.

(ii) Each employer, who has a place of employment in which benzene is present, shall inspect each workplace and work operation to determine if any employee may be exposed to benzene through eye contact or repeated skin contact.

(2) Frequency of monitoring. The monitoring required under paragraph (e) (1) of this section shall be conducted, and the results obtained, within thirty days of the effective date of this section and thereafter repeated quarterly for employees whose exposure is found to be less than 1 ppm, and monthly for those employees whose exposure is found to be in excess of the permissible exposure limit. The employer shall continue monthly measurements until at least two consecutive measurements taken at least seven (7) days apart are below the permissible exposure limit, and thereafter the employer shall measure quarterly.

(3) Additional monitoring. Whenever there has been a production, process, or control change which may result in new or additional exposure to benzene, or whenever the employer has any other reason to suspect a change which may result in new or additional exposures to benzene, additional monitoring which complies with paragraph (e)(1) of this section shall be made.

(4) Employee notification. (i) Within 5 working days after the receipt of measurement results, the employer shall notify each employee in writing of the exposure measurements which represent that employee's exposure.

(ii) Where the results reveal the employee's exposure to be over the permissible exposure limit, this notification shall also include the corrective action being taken to reduce exposure to or below the permissible exposure limit.

(5) Accuracy of measurement. The method of measurement shall have an accuracy, to a confidence level of 95 percent, of not less than plus or minus 25 percent for concentrations of benzene greater than or equal to 1 ppm.

(6) Employee exposure. For the purposes of this section, employee exposure is that exposure which would occur if the employee were not using a respirator.

(f) Methods of compliance. The employer shall control employee exposures to airborne concentrations of benzene to or below the permissible exposure limit, and shall protect against employee exposure to eye or repeated skin contact with benzene, by engineering controls, work practices and personal protective devices and equipment as, follows:

(1) Engineering controls. The employer shall develop and implement, as soon as possible, feasible engineering controls to reduce the airborne concentration of benzene to or below the permissible exposure limit.

(2) Work practices. The employer shall examine each work area in which benzene is present and shall institute, as soon as possible, work practices to reduce employee exposure to benzene to or below the permissible exposure limit. The work practices shall be described in writing and shall include, among other things, the following:

(i) Limiting access to work areas where benzene is present to authorized personnel only;

(ii) Prohibiting smoking and the consumption of food and beverages in work area where benzene is present; and

(iii) Establishing good maintenance and housekeeping including the prompt cleanup of spills, repair of leaks, etc.

(3) Respiratory protection. Whenever engineering and work practice controls which can be instituted are not sufficient to reduce exposures to or below the permissible exposure limit, they shall be used nonetheless to reduce exposure to the lowest practicable level, and shall be supplemented by the use of respirators in accordance with paragraph (g) of the section.

(g) Respirators--(1) Required use. The employer shall assure that respirators are used where required under this section to reduce employee exposure to or below the permissible exposure limit, and in emergencies.

(2) Respirator selection. (i) Where respirators are required under this section, the employer shall select and provide the appropriate respirator from Table I below and shall assure that the employee uses the respirator provided.

(ii) The employer shall select respirators from among those approved by the National Institute for Occupational Safety and Health under the provisions of 30 CFR Part 11.

Table I--RESPIRATORY PROTECTION FOR BENZENE

<u>Concentration of benzene or condition of use</u>	<u>Respirator type</u>
(a) Less than or equal to 10 ppm.....	(1) Chemical cartridge respirator with organic vapor cartridges and half mask; or (2) Any supplied air respirator with half mask.
(b) Less than or equal to 50 ppm.....	(1) Chemical cartridge respirator with organic vapor cartridges and full facepiece; or (2) Any supplied air respirator with full face piece; or (3) Any organic vapor gas mask; or (4) Any self-contained breathing apparatus with full facepiece.
(c) Less than or equal to 1,000 ppm.....	(1) Supplied air respirator with half masks in positive pressure mode.
(d) Less than or equal to 2,000 ppm.....	(1) Supplied air respirator with full facepiece, helmet, or hood, in positive pressure mode.
(e) Less than or equal to 10,000 ppm....	(1) Supplied air respirator and auxiliary self-contained facepiece in positive pressure mode; or (2) Open circuit self-contained breathing apparatus with full facepiece in positive pressure mode.
(f) Escape.....	(1) Any organic vapor gas mask; or (2) Any self-contained breathing apparatus with full facepiece.

(3) Respirator program. The employer shall institute a respiratory protection program in accordance with §1910.134 (b), (d), (e), and (f).

(4) Where air-purifying respirators are used (cartridge, canister or gas mask), the air-purifying canisters or cartridges shall be replaced prior to the expiration of their service life or the end of the shift in which they are first used, whichever occurs first.

(h) Protective clothing and equipment. Where eye or repeated skin contact with liquid benzene may occur, employers shall provide and assure that employees wear impermeable protective clothing and appropriate equipment to protect the area of the body likely to come in contact with liquid benzene.

(i) Medical surveillance. (1) Each employer shall make available a medical surveillance program for all employees who are or will be exposed to benzene. The medical surveillance program shall consist of:

(i) A history which includes past work exposures to benzene or any other hematologic toxins, a family history of hematological neoplasms, a history of blood dyscrasias including genetically related hemoglobin alterations, bleeding abnormalities, abnormal function of formed blood elements, a history of renal or liver dysfunction, a history of drugs routinely taken, alcoholic intake and systemic infections.

(ii) A complete blood count including a differential white blood cell count; and

(iii) Additional tests shall be conducted where, in the opinion of the examining physician, alterations in the components of the blood are related to benzene exposure.

(2) All medical procedures shall be performed by or under the supervision of a licensed physician, and shall be provided by the employer without cost to the employee.

(3) Medical surveillance and testing of each employee shall be conducted within thirty days of the effective date of this section, and quarterly thereafter. If an employee is accidentally or otherwise exposed to benzene by ingestion, inhalation, skin or eye contact, or for any reason, an employee develops signs and symptoms commonly associated with exposure to benzene, the employer shall provide appropriate medical examinations and emergency treatment.

(4) Information provided to the physician. The employer shall provide the following information to the examining physician:

(i) A copy of this regulation and its appendixes;

(ii) A description of the affected employee's duties as they relate to the employee's exposure.

(iii) The employee's representative exposure level; and

(iv) A description of any personal protective equipment used or to be used.

(5) Physician's written opinion. (i) The employer shall obtain a written opinion from the examining physician which shall include:

(a) The results of the medical testing;

(b) the physician's opinion as to whether the employee has any detected medical condition which would place the employee at increased risk of material impairment of the employee's health from exposure to benzene;

(c) Any recommended limitations upon the employee's exposure to benzene or upon the use of protective clothing and equipment such as respirators; and

(d) A statement that the employee has been informed by the physician of any medical conditions which require further examination or treatment.

(ii) The employer shall instruct the physician not to reveal in the written opinion specific findings or diagnoses unrelated to occupational exposure.

(iii) The employer shall provide a copy of the written opinion to the affected employee.

(j) Employee information and training--(1) Training program. Within fifteen days of the effective date of this section, the employer shall provide a training program for employees assigned to workplace areas where benzene is present and shall assure that each affected employee is informed of the following:

(i) The information contained in the substance data sheet for benzene which is contained in Appendix A of this section;

(ii) The quantity, location, manner of use, release or storage or benzene and the specific nature of operations which could result in exposure above the permissible exposure limit, as well as necessary protective steps;

(iii) The purpose, proper use, and limitation of respiratory devices as specified in §1910.134;

(iv) The purpose and a description of the medical testing program required by paragraph (j)(1)(i) of this section and the information contained in Appendix C of this section; and

(v) The contents of this standard.

(2) Access to training materials. (i) The employer shall make a copy of this standard and its appendixes readily available to all affected employees.

(ii) The employer shall provide, upon request, all materials relating to the employee information and training program to the Assistant Secretary and the Director.

(k) Signs. (1) The employer shall post signs to clearly designate all work areas where benzene may be present, bearing the legend:

DANGER

BENZENE

CANCER HAZARD

(2) Where the permissible exposure limit is exceeded, the signs shall also include the legend: Respirator required.

(3) The employer shall assure that no statement appear on or near any required sign which contradicts or detracts from the required information.

(1) Recordkeeping--(1) Exposure measurements. The employer shall establish and maintain an accurate record of all measurements required by paragraph (e) of this section.

(i) This record shall include:

(a) The dates, number, duration and results of each of the samples taken, including a description of the sampling procedure used to determine representative employee exposures.

(b) A description of the sampling and analytical methods used;

(c) Type of respiratory protective devices worn, if any; and

(d) Name, social security number, and job classification of the employee monitored and all other employees whose exposure the measurement is intended to represent.

(ii) This record shall be maintained during the effective period of this section.

(2) Medical surveillance. The employer shall establish and maintain an accurate record for each employee subject to medical surveillance as required by paragraph (1)(i) of this section;

(i) This record shall include:

(a) A copy of the physician's written opinion:

(b) Any employee medical complaints related to exposure to benzene; and

(c) A copy of the information provided to the physician as required by paragraph (1)(i)(4) of this section;

(ii) This record shall be maintained during the effective period of this section.

(3) Availability. (i) All records required to be maintained by this section shall be made available upon request to the Assistant Secretary and the Director for examination and copying.

(ii) Employee exposure measurement records as required by this section shall be made available for examination and copying to affected employees, and their designated representatives.

(iii) Former employees and the employees' designated representatives shall have access to such records as will indicate their own exposure to benzene.

(iv) Employee medical records required to be maintained by this section shall be made available upon request for examination and copying to a physician designated by the affected employee or former employee.

(m) Observation of monitoring--(1) Employee observation. The employer shall provide affected employees, or their designated representatives, an opportunity to observe any measuring or monitoring of employee exposure to benzene conducted pursuant to paragraph (e) of this section.

(2) Observation procedures (i) When observation of the measuring or monitoring of employee exposure to benzene requires entry into an area where the use of protective clothing and equipment or respirators is required, the employer shall provide the observer with personal protective devices required to be worn by employees working in the area, assure the use of such equipment, and require the observer to comply with all other applicable safety and health procedures.

(ii) Without interfering with the measurement, observers shall be entitled to:

(a) Receive an explanation of the measurement procedures;

(b) Observe all steps related to the measurement of airborne concentrations of benzene performed at the place of exposure; and

(c) Record the results obtained.

(n) Effective data: This section shall become effective May 21, 1977.

(o) Appendixes. The information contained in the appendixes is not intended by itself, to create any additional obligations not otherwise imposed or to detract from any existing obligation.

Appendix A--Substance Safety Data Sheet

BENZENE

I. Substance Identification

A. Substance. Benzene.

B. Permissible Exposure. Except as to retail gasoline stations and operations which use liquids containing benzene in amounts greater than 1% by volume, or the benzene vapor released by any such liquids.

1. Airborne. 1 part of benzene vapor per million parts of air (1 ppm); time weighted average (TWA) for an 8-hour workday for a 40-hour week, with a ceiling concentration of 5 ppm.

2. Dermal. Eye contact and repeated skin contact with liquid benzene shall be prohibited.

C. Appearance and odor. Benzene is a clear, colorless liquid with a pleasant, sweet odor. The odor of benzene does not provide adequate warning of its hazard.

II. Health Hazard Data

A. Ways in which the benzene affects your health. Benzene can affect your health if you inhale it, or if it comes in contact with your skin or eyes. Benzene may also be harmful if you happen to swallow it.

B. Effect of overexposure. 1. Short-term (acute) overexposure: If you are overexposed to high concentrations of benzene well above the levels where its odors are first recognizable, you may feel breathless, irritable, euphoric, or giddy; you may experience irritation in eyes, nose, and respiratory tract. You may develop a headache, feel dizzy, nauseous, or experience unsteadiness in walking. Severe exposures may lead to convulsions.

2. Long-term (chronic) exposure: Repeated and prolonged exposure of benzene may cause headache, fatigue, exhaustion, tendency to bleed, nervousness, sleeplessness, shortness of breath, and serious blood disorders, including leukemia.

III. Protective Clothing and Equipment

A. Respirators. Respirators are required for those operations in which engineering controls or work practice controls are not available to reduce exposure to the permissible level. If respirators are worn, they must have a National Institute for Occupational Safety and Health (NIOSH) seal of approval. If you experience difficulty breathing while wearing a respirator, tell your employer.

B. Protective Clothing. You must wear impervious protective clothing (such as boots, gloves, sleeves, aprons, etc.) over any parts of your body that could be repeatedly exposed to liquid benzene.

C. Eye and Face Protection. You must wear splash proof safety goggles if it is possible that benzene may get into your eyes. In addition, you should wear a face shield if your face could be splashed with benzene liquid.

IV. Emergency and First Aid Procedures

A. Eye and face exposure. If benzene is splashed in your eyes, wash it out immediately with large amounts of water. Call a doctor as soon as possible.

B. Skin exposure. If benzene is spilled on your clothing or skin, remove the contaminated clothing and wash the exposed skin with large amounts of water and soap immediately. Wash contaminated clothing before you wear it again.

C. Breathing. If you or any other person breathes in large amounts of benzene, get the exposed person to fresh air at once. Apply artificial respiration if breathing has stopped. Call a doctor as soon as possible.

D. Swallowing. If benzene has been swallowed and the patient is conscious, do not induce vomiting. Call a doctor immediately.

V. Medical Requirements

If you are exposed to benzene your employer is required to provide the following medical procedures within thirty days of the effective date of this standard, consisting of a medical history and laboratory tests. These tests shall be provided without cost to you.

VII. Observation of Monitoring

Your employer is required to perform measurements that are representative of your exposure to benzene and you are entitled to observe the monitoring procedure. You are entitled to receive an explanation of the measurement procedure, observe the steps taken in the measurement procedure, and to record the results obtained. When the monitoring procedure is taking place in an area where respirators or personal protective clothing and equipment are required to be worn, you must also be provided with and must wear the protective clothing and equipment

VIII. Access to Records

You or your representative are entitled to see the records of measurements of your exposure to benzene upon request to your employer. Your medical examination records can be furnished to your physician upon request to your employer.

IX. Precautions for Safe Use, Handling and Storage

Benzene liquid is highly flammable. It should be stored in tightly closed containers in a cool, well ventilated area. Benzene vapor may form explosive mixtures in air. All sources of ignition must be controlled. You should use non-sparking tools when opening or closing benzene containers. You must ground or bond metal benzene containers. Fire extinguishers, where provided, must be readily available and you should know where they are located and how to operate them. Smoking is prohibited in areas where benzene is used or stored. Ask your supervisor where benzene is used on your work area and for additional plant safety rules.

Appendix B--Substance Technical Guidelines

BENZENE

I. Physical and Chemical Data

A. Substance Identification

1. Synonyms. Benzol, coal naphtha, cyclohexatriene, phene, phenyl hydride, pyrobenzol. (Benzin, petroleum benzin, and benzine, do not contain benzene).

2. Formula. C₆H₆ (CAS Registry Number 000071432)

B. Physical Data

1. Boiling point (760 mm Hg): 80.1 C (176F).

2. Specific Gravity (water = 1):0.879.
3. Vapor Density (air = 1):2.7.
4. Melting Point: 5/5 C (42F).
5. Vapor Pressure at 20 C (68F):75 mm Hg.
6. Solubility in Water: .06%
7. Evaporation Rate (ether = 1):2.8.
8. Appearance and Odor: Clear, colorless liquid with a distinctive sweet odor.

II. Fire, Explosion and Reactivity Hazard Data

- A. Fire. 1. Flash Point (closed cup): -11 C (12F).
2. Autoignition Temperature: 580 C (1076F).
3. Flammable Limits in Air. % by Volume: Lower : 1.3% Upper: 7.1%.
4. Extinguishing Media: Carbon dioxide, dry chemical, or foam.
5. Special Fire-Fighting Procedures: Do not use solid stream of water, since stream will scatter and spread fire. Water spray can be used to keep fire exposed containers cool.
6. Unusual fire and explosion hazards: Benzene is a flammable liquid. Its vapors can form explosive mixtures. All ignition sources must be controlled when benzene is used, handled, or stored. Where liquid or vapor may be released, such areas shall be considered as hazardous locations. Benzene vapors are heavier than air; thus the vapors may travel along the ground and be ignited by open flames or sparks at locations remote from the site at which benzene is handled.
7. Benzene is classified as a 1 Flammable liquid for the purpose of conforming to the requirements of 29 CFR 1910.106. A concentration exceeding 3250 ppm is considered a potential fire or explosion hazard. Locations where benzene may be present in quantities sufficient to produce explosive or ignitable mixtures are considered Class I Group D for the purposes of conforming to the requirement of 29 CFR 1910.309.

- B. Reactivity. 1. Conditions contributing to instability: Heat.
2. Incompatibility: Heat and oxidizing materials.
3. Hazardous decomposition products: Toxic gases and vapors (such as carbon monoxide).

III. Spill and Leak Procedures

A. Steps to be taken if the material is released or spilled. Large amounts of water should be used to flush the spills. Do not flush benzene into confined space, such as a sewer, because of explosive danger. Remove all ignition sources. Ventilate enclosed places.

B. Waste Disposal Method. Disposal methods must conform to other jurisdictional regulations. If allowed, benzene may be disposed of: (a) By absorbing it in dry sand or earth and disposing in a sanitary land fill; (b) if small quantities, by removing it to a safe location from buildings or other combustible sources, pouring it in dry sand or earth and cautiously igniting it; (c) if large quantities, by atomizing it in a suitable combustion chamber.

IV. Monitoring and Measurement Procedures

A. Normal Monitoring Program; Measurements taken for the purpose of determining employee exposure are best taken such that the representative average 8-hour exposure may be determined from a single 8-hour sample or two (2) 4-hour samples. Short-time interval samples (or grab samples may also be used to determine average exposure level if a minimum of five (5) measurements is taken in a random manner over the 8-hour work shift. Random sampling means that any portion of the work shift has the same chance of being sampled as any other. The arithmetic average of all such random samples taken on one (1) work shift is an estimate of an employee's average level of exposure for that work shift. NIOSH recommends that samples be collected at a sampling rate of one liter per minute for a minimum of two hours. Air samples should be taken in the employee's breathing zone (air that would nearly represent that taken in by the employee). Sampling and analysis should be performed by gas adsorption tubes with subsequent chemical analysis, by gas chromatography of those areas most likely to represent the highest airborne concentration of benzene where employees are exposed. Methods meeting the prescribed accuracy and precision requirements are available in the "NIOSH Manual of Analytical Methods."

V. Miscellaneous Precautions

A. High Exposures to benzene can occur when transferring the liquid from one container to another. Such operations should be well ventilated and good work practices should be established to avoid spills.

B. Non-sparking tools should be used to open benzene containers which should be effectively grounded and bonded prior to opening and pouring.

C. Employers should advise employees of all plant areas and operations where exposure to benzene could occur. A few of the common operations in which high exposures to benzene may be encountered are: manufacture of styrene, phenol, cyclohexane, pesticides, and detergents.

Appendix C--Medical Surveillance Guidelines for Benzene

I. Route of Entry

Inhalation: possible skin absorption.

II. Toxicology

Benzene is primarily an inhalation hazard. Systemic absorption cause depression of the hematopoietic system. Inhalation of high concentrations can affect the central nervous system function. Aspiration of small amounts of liquid benzene immediately causes pulmonary edema and hemorrhage of pulmonary tissue. Skin absorption through intact skin is negligible. However, absorption will be accelerated in the case of injured skin, and benzene may be more readily absorbed if it is present in a mixture or as a contaminate in solvents which are readily absorbed. Defatting action of benzene may produce primary irritation upon repeated or prolonged contact with the skin. High concentrations are irritating to the mucous membranes of the eyes, nose, and respiratory tract.

III. Signs and Symptoms

Benzene is poorly absorbed through the skin, however, direct contact may cause erythema or blistering. Repeated or prolonged contact may result in drying, scaling, dermatitis, or precipitate development of secondary skin infections. Local effects of benzene vapor or liquid on the eye are slight. Only at very high concentrations is there any smarting sensation in the eye. Droplet contamination of the eye by benzene causes a moderate burning sensation, but only slight transient injury of the epithelial cell, with the eye recovering rapidly. Inhalation of high concentrations of benzene may have an initial stimulatory effect on the central nervous system characterized by exhilaration, nervous excitation, and/or giddiness, followed by a period of depression, drowsiness, fatigue, or vertigo. There may be sensation of tightness in the chest accompanied by breathlessness and ultimately the victim may lose consciousness. Convulsions and tremors occur frequently, and death may follow from respiratory paralysis or circulatory collapse in a few minutes to several hours following severe exposures. The insidious and often irreversible effect on the blood forming system of prolonged exposure to small quantities of benzene vapor is of extreme importance. These effects have been noted to occur at concentrations of benzene which may not cause irritation of mucous membranes, or any unpleasant sensory effects. Early signs and symptoms of benzene morbidity are varied and vague, and not specific for benzene exposure. Subjective complaints of headache, dizziness, and loss of appetite may precede or proceed clinical symptomology. Bleeding from the nose, gums, or mucous membranes and the development of purpuric spots may occur as the condition progresses. Rapid pulse and low blood pressure in addition to a physical appearance of anemia may accompany a subjective complaint of shortness of breath. Clinical evidence of leucopenia and anemia are the most common abnormalities reported, however, macrocytosis and thrombocytopenia are also frequently present. Bone marrow may appear normal, aplastic, or hyperplastic and may not in all situations correlate with peripheral blood findings indicating hypo-hyperactivity of blood forming tissues. There are great variations in the susceptibility to benzene morbidity which prohibits the identification of "typical" blood picture. The effects of prolonged benzene exposure may appear after several weeks or years after the actual exposure has ceased. Development of leukemia also results from exposure to benzene.

IV. Treatment

Remove from exposure immediately, give oxygen or artificial resuscitation if indicated. Flush eyes and wash contaminated skin. Symptoms of non-specific nervous disturbances may persist following severe exposures. Recovery from mild exposures is usually rapid and complete.

V. Surveillance and Preventive

A. Other considerations. Benzene can cause both acute and chronic effects. It is important that the physician become familiar with the operating conditions in which exposure to benzene occurs. Those with skin disease may not tolerate the wearing of protective clothing and those with chronic respiratory disease may not tolerate the wearing of negative pressure respirators.

B. Surveillance and screening. Medical histories and laboratory examinations are required for each employee subject to exposure to benzene. The employer must screen employees for history of certain medical conditions (listed below) which might place the employee at increased risk from exposure.

1. Liver disease. The primary site of biotransformation and detoxification of benzene is the liver. Liver dysfunctions likely to inhibit the conjugation reactions will tend to promote the toxic actions of benzene. These precautions should be considered before exposing persons with impaired liver function to benzene vapors.

2. Renal disease. Although benzene is not known as a kidney toxin the importance of the organ in the elimination of toxic substances and metabolites justifies special consideration in those with possible impairment of renal function.

3. Skin disease. Benzene is a defatting agent and can cause dermatitis on prolonged exposure. Persons with preexisting skin disorders may be more susceptible to the effects of benzene.

4. Blood dyscrasias. Benzene is a hematopoietic depressant. Persons with existing blood disorders may be more susceptible to the effects of benzene.

References

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- (Secs. 4, 6, 8, 84 Stat. 1593, 1599 (29 U.S.C. 653, 655, 657); Secretary of Labor's Order 8-76 (41 FR 25059); 29 CFR Part 1911.)
- (42 FR 22525, May 3, 1977, as amended at 42 FR 23601, May 10, 1977; 42 FR 26429, May 24, 1977)

APPENDIX II

NIOSH Manual of Analytical Methods,
Second Edition, Volume 1

U.S. Department of Health, Education, and Welfare
April 1977

ORGANIC SOLVENTS IN AIR

Physical and Chemical Analysis Branch

Analytical Method

Analyte:	Organic Solvents (See Table 1)	Method No.:	P&CAM 127
Matrix:	Air	Range:	For the specific compound, refer to Table 1
Procedure:	Adsorption on charcoal desorption with carbon disulfide, GC		
Date Issued:	9/15/72	Precision:	10.5% RSD
Date Revised:	2/15/77	Classification:	See Table 1

1. Principle of the Method

- 1.1 A known volume of air is drawn through a charcoal tube to trap the organic vapors present.
- 1.2 The charcoal in the tube is transferred to a small, graduated test tube and desorbed with carbon disulfide.
- 1.3 An aliquot of the desorbed sample is injected into a gas chromatograph.
- 1.4 The area of the resulting peak is determined and compared with areas obtained from the injection of standards.

2. Range and Sensitivity

The lower limit in mg sample for the specific compound at 16×1 attenuation on a gas chromatograph fitted with a 10:1 splitter is shown in Table 1. This value can be lowered by reducing the attenuation or by eliminating the 10:1 splitter.

3. Interferences

- 3.1 When the amount of water in the air is so great that condensation actually occurs in the tube, organic vapors will not be trapped. Preliminary experiments indicate that high humidity severely decreases the breakthrough volume.
- 3.2 When two or more solvents are known or suspected to be present in the air, such information (including their suspected identities), should be transmitted with the sample, since with differences in polarity, one may displace another from the charcoal.
- 3.3 It must be emphasized that any compound which has the same retention time as the specific compound under study at the operating conditions described in this method is an interference. Hence, retention time data on a single column, or even on a number of columns, cannot be considered as proof of chemical identity. For this reason it is important that a sample of the bulk solvent(s) be submitted at the same time so that identity(ies) can be established by other means.

- 3.4 If the possibility of interference exists, separation conditions (column packing, temperatures, etc.) must be changed to circumvent the problem.

4. Precision and Accuracy

- 4.1 The mean relative standard deviation of the analytical method is 8% (11.4).
- 4.2 The mean relative standard deviation of the analytical method plus field sampling using an approved personal sampling pump is 10% (11.4). Part of the error associated with the method is related to uncertainties in the sample volume collected. If a more powerful vacuum pump with associated gas-volume integrating equipment is used, sampling precision can be improved.
- 4.3 The accuracy of the overall sampling and analytical method is 10% (NIOSH-unpublished data) when the personal sampling pump is calibrated with a charcoal tube in the line.

5. Advantages and Disadvantages of the Method

- 5.1 The sampling device is small, portable, and involves no liquids. Interferences are minimal, and most of those which do occur can be eliminated by altering chromatographic conditions. The tubes are analyzed by means of a quick, instrumental method. The method can also be used for the simultaneous analysis of two or more solvents suspected to be present in the same sample by simply changing gas chromatographic conditions from isothermal to a temperature-programmed mode of operation.
- 5.2 One disadvantage of the method is that the amount of sample which can be taken is limited by the number of milligrams that the tube will hold before overloading. When the sample value obtained for the backup section of the charcoal tube exceeds 25% of that found on the front section, the possibility of sample loss exists. During sample storage, the more volatile compounds will migrate throughout the tube until equilibrium is reached (33% of the sample on the backup section).
- 5.3 Furthermore, the precision of the method is limited by the reproducibility of the pressure drop across the tubes. This drop will affect the flow rate and cause the volume to be imprecise, because the pump is usually calibrated for one tube only.

6. Apparatus

- 6.1 An approved and calibrated personal sampling pump for personal samples. For an area sample, any vacuum pump whose flow can be determined accurately at 1 liter per minute or less.
- 6.2 Charcoal tubes: glass tube with both ends flame sealed, 7 cm long with a 6-mm O.D. and a 4-mm I.D., containing 2 sections of 20-40 mesh activated charcoal separated by a 2-mm portion of urethane foam. The activated charcoal is prepared from coconut shells and is fired at 600°C prior to packing. The absorbing section contains 100 mg of charcoal, the backup section 50 mg. A 3-mm portion of urethane foam is placed between the outlet end of the tube and the backup section. A plug of silylated glass wool is placed in front of the absorbing section. The pressure drop across the tube must be less than one inch of mercury at a flow rate of 1 lpm.
- 6.3 Gas chromatograph equipped with a flame ionization detector.
- 6.4 Column (20 ft \times $\frac{1}{8}$ in) with 10% FFAP stationary phase on 80/100 mesh, acid-washed DMCS Chromosorb W solid support. Other columns capable of performing the required separations may be used.

- 6.5 A mechanical or electronic integrator or a recorder and some method for determining peak area.
- 6.6 Microcentrifuge tubes, 2.5 ml, graduated.
- 6.7 Hamilton syringes: 10 μ l, and convenient sizes for making standards.
- 6.8 Pipets: 0.5-ml delivery pipets or 1.0-ml type graduated in 0.1-ml increments.
- 6.9 Volumetric flasks: 10 ml or convenient sizes for making standard solutions.

7. Reagents

- 7.1 Spectroquality carbon disulfide (Matheson Coleman and Bell).
- 7.2 Sample of the specific compound under study, preferably chromatquality grade.
- 7.3 Bureau of Mines Grade A helium.
- 7.4 Prepurified hydrogen.
- 7.5 Filtered compressed air.

8. Procedure

- 8.1 **Cleaning of Equipment:** All glassware used for the laboratory analysis should be detergent washed and thoroughly rinsed with tap water and distilled water.
- 8.2 **Calibration of Personal Pumps.** Each personal pump must be calibrated with a representative charcoal tube in the line. This will minimize errors associated with uncertainties in the sample volume collected.
- 8.3 **Collection and Shipping of Samples**
 - 8.3.1 Immediately before sampling, the ends of the tube should be broken to provide an opening at least one-half the internal diameter of the tube (2 mm).
 - 8.3.2 The small section of charcoal is used as a back-up and should be positioned nearest the sampling pump.
 - 8.3.3 The charcoal tube should be vertical during sampling to reduce channeling through the charcoal.
 - 8.3.4 Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.
 - 8.3.5 The flow, time, and/or volume must be measured as accurately as possible. The sample should be taken at a flow rate of 1 lpm or less to attain the total sample volume required. The minimum and maximum sample volumes that should be collected for each solvent are shown in Table I. The minimum volume quoted must be collected if the desired sensitivity is to be achieved.
 - 8.3.6 The temperature and pressure of the atmosphere being sampled should be measured and recorded.
 - 8.3.7 The charcoal tubes should be capped with the supplied plastic caps immediately after sampling. Under no circumstances should rubber caps be used.
 - 8.3.8 One tube should be handled in the same manner as the sample tube (break, seal, and transport), except that no air is sampled through this tube. This tube should be labeled as a blank.
 - 8.3.9 Capped tubes should be packed tightly before they are shipped to minimize tube breakage during shipping.

8.3.10 Samples of the suspected solvent(s) should be submitted to the laboratory for qualitative characterization. These liquid bulk samples should not be transported in the same container as the samples or blank tube. If possible, a bulk air sample (at least 50 l air drawn through tube) should be shipped for qualitative identification purposes.

8.4 Analysis of Samples

8.4.1 Preparation of Samples. In preparation for analysis, each charcoal tube is scored with a file in front of the first section of charcoal and broken open. The glass wool is removed and discarded. The charcoal in the first (larger) section is transferred to a small stoppered test tube. The separating section of foam is removed and discarded; the second section is transferred to another test tube. These two sections are analyzed separately.

8.4.2 Desorption of Samples. Prior to analysis, one-half ml of carbon disulfide is pipetted into each test tube. (All work with carbon disulfide should be performed in a hood because of its high toxicity.) Tests indicate that desorption is complete in 30 minutes if the sample is stirred occasionally during this period.

8.4.3 GC Conditions. The typical operating conditions for the gas chromatograph are:

1. 85 cc/min. (70 psig) helium carrier gas flow.
2. 65 cc/min. (24 psig) hydrogen gas flow to detector.
3. 500 cc/min. (50 psig) air flow to detector.
4. 200°C injector temperature.
5. 200°C manifold temperature (detector).
6. Isothermal oven or column temperature — refer to Table 1 for specific compounds.

8.4.4 Injection. The first step in the analysis is the injection of the sample into the gas chromatograph. To eliminate difficulties arising from blowback or distillation within the syringe needle, one should employ the solvent flush injection technique. The 10 µl syringe is first flushed with solvent several times to wet the barrel and plunger. Three microliters of solvent are drawn into the syringe to increase the accuracy and reproducibility of the injected sample volume. The needle is removed from the solvent, and the plunger is pulled back about 0.2 µl to separate the solvent flush from the sample with a pocket of air to be used as a marker. The needle is then immersed in the sample, and a 5-µl aliquot is withdrawn, taking into consideration the volume of the needle, since the sample in the needle will be completely injected. After the needle is removed from the sample and prior to injection, the plunger is pulled back a short distance to minimize evaporation of the sample from the tip of the needle. Duplicate injections of each sample and standard should be made. No more than a 3% difference in area is to be expected.

8.4.5 Measurement of area. The area of the sample peak is measured by an electronic integrator or some other suitable form of area measurement, and preliminary results are read from a standard curve prepared as discussed below.

8.5 Determination of Desorption Efficiency

8.5.1 Importance of determination. The desorption efficiency of a particular compound can vary from one laboratory to another and also from one batch of charcoal to another. Thus, it is necessary to determine at least once the percentage of the specific compound that is removed in the desorption process for a given compound, provided the same batch of charcoal is used. NIOSH has found that the desorption efficiencies for the compounds in Table 1 are between 81% and 100% and vary with each batch of charcoal.

8.5.2 Procedure for determining desorption efficiency. Activated charcoal equivalent to the amount in the first section of the sampling tube (100 mg) is measured into a 5-cm, 4-mm I.D. glass tube, flame-sealed at one end (similar to commercially available culture tubes). This charcoal must be from the same batch as that used in obtaining the samples and can be obtained from unused charcoal tubes. The open end is capped with Parafilm. A known amount of the compound is injected directly into the activated charcoal with a microliter syringe, and the tube is capped with more Parafilm. The amount injected is usually equivalent to that present in a 10-liter sample at a concentration equal to the federal standard.

At least five tubes are prepared in this manner and allowed to stand for at least overnight to assure complete absorption of the specific compound onto the charcoal. These five tubes are referred to as the samples. A parallel blank tube should be treated in the same manner except that no sample is added to it. The sample and blank tubes are desorbed and analyzed in exactly the same manner as the sampling tube described in Section 8.4.

Two or three standards are prepared by injecting the same volume of compound into 0.5 ml of CS₂ with the same syringe used in the preparation of the sample. These are analyzed with the samples.

The desorption efficiency equals the difference between the average peak area of the samples and the peak area of the blank divided by the average peak area of the standards, or

$$\text{desorption efficiency} = \frac{\text{Area sample} - \text{Area blank}}{\text{Area standard}}$$

9. Calibration and Standards

It is convenient to express concentration of standards in terms of mg/0.5 ml CS₂ because samples are desorbed in this amount of CS₂. To minimize error due to the volatility of carbon disulfide, one can inject 20 times the weight into 10 ml of CS₂. For example, to prepare a 0.3 mg/0.5 ml standard, one would inject 6.0 mg into exactly 10 ml of CS₂ in a glass-stoppered flask. The density of the specific compound is used to convert 6.0 mg into microliters for easy measurement with a microliter syringe. A series of standards, varying in concentration over the range of interest, is prepared and analyzed under the same GC conditions and during the same time period as the unknown samples. Curves are established by plotting concentration in mg/0.5 ml versus peak area.

NOTE: Since no internal standard is used in the method, standard solutions must be analyzed at the same time that the sample analysis is done. This will minimize the effect of known day-to-day variations and variations during the same day of the FID response.

10. Calculations

10.1 The weight, in mg, corresponding to each peak area is read from the standard curve for the particular compound. No volume corrections are needed, because the standard curve is based on mg/0.5 ml CS₂ and the volume of sample injected is identical to the volume of the standards injected.

10.2 Corrections for the blank must be made for each sample.

$$\text{Correct mg} = \text{mg}_s - \text{mg}_b$$

where:

mg_a = mg found in front section of sample tube

mg_b = mg found in front section of blank tube

A similar procedure is followed for the backup sections.

10.3 The corrected amounts present in the front and backup sections of the same sample tube are added to determine the total measured amount in the sample.

10.4 This total weight is divided by the determined desorption efficiency to obtain the corrected mg per sample.

10.5 The concentration of the analyte in the air sampled can be expressed in mg per m³.

$$mg/m^3 = \frac{\text{Corrected mg (Section 10.4)} \times 1000 \text{ (liter/m}^3\text{)}}{\text{Air volume sampled (liters)}}$$

10.6 Another method of expressing concentration is ppm (corrected to standard conditions at 25°C and 760 mm Hg).

$$ppm = mg/m^3 \times \frac{24.45}{MW} \times \frac{760}{P} \times \frac{(T + 273)}{298}$$

where:

P = pressure (mm Hg) of air sampled

T = temperature (°C) of air sampled

24.45 = molar volume (liter/mole) at 25°C and 760 mm Hg

MW = molecular weight

760 = standard pressure (mm Hg)

298 = standard temperature (°K)

11. References

- 11.1 White, L. D., D. G. Taylor, P. A. Mauer, and R. E. Kupel, "A Convenient Optimized Method for the Analysis of Selected Solvent Vapors in the Industrial Atmosphere", Am Ind Hyg Assoc J 31:225, 1970.
- 11.2 Young, D. M. and A. D. Crowell, Physical Adsorption of Gases, pp. 137-146. Butterworths, London, 1962.
- 11.3 Federal Register, 37:202:22139-22142, October 18, 1972.
- 11.4 NIOSH Contract HSM-99-72-98, Scott Research Laboratories, Inc., "Collaborative Testing of Activated Charcoal Sampling Tubes for Seven Organic Solvents", pp. 4-22, 4-27, 1973.

TABLE 1
Parameters Associated With P&CAB Analytical Method No. 127

Organic Solvent	Method Classification	Detection limit (mg/sample)	Sample Volume (liters)		GC Column Temp.(°C)	Molecular Weight
			Minimum ^(a)	Maximum ^(b)		
Acetone	D	—	0.5	7.7	60	58.1
Benzene	A	0.01	0.5	55	90	78.1
Carbon tetrachloride	A	0.20	10	60	60	154.0
Chloroform	A	0.10	0.5	13	80	119
Dichloromethane	D	0.05	0.5	3.8	85	84.9
p-Dioxane	A	0.05	1	18	100	88.1
Ethylene dichloride	D	0.05	1	12	90	99.0
Methyl ethyl ketone	B	0.01	0.5	13	80	72.1
Styrene	D	0.10	1.5	34	150	104
Tetrachloroethylene	B	0.06	1	25	130	166
1,1,2-trichloroethane	B	0.05	10	97	150	133
1,1,1-trichloroethane (methyl chloroform)	B	0.05	0.5	13	150	133
Trichloroethylene	A	0.05	1	17	90	131
Toluene	B	0.01	0.5	22	120	92.1
Xylene	A	0.02	0.5	31	100	106

(a) Minimum volume, in liters, required to measure 0.1 times the OSHA standard

(b) These are breakthrough volumes calculated with data derived from a potential plot (11.2) for activated coconut charcoal. Concentrations of vapor in air at 5 times the OSHA standard (11.3) or 500 ppm, whichever is lower, 25 °C, and 760 torr were assumed. These values will be as much as 50% lower for atmospheres of high humidity. The effects of multiple contaminants have not been investigated, but it is suspected that less volatile compounds may displace more volatile compounds (See 3.1 and 3.2)

APPENDIX III

National Institute for Occupational Safety and Health (NIOSH)

Regulators

Chapter I

Mining Enforcement, Safety Administration

Title 30--Mineral Resources

SUBCHAPTER B--RESPIRATORY PROTECTIVE APPARATUS;
TESTS FOR PERMISSIBILITY; FEES

PART II--RESPIRATORY PROTECTIVE DEVICES; TESTS FOR PERMISSIBILITY; FEES

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- 11.1 Purpose.
- 11.2 Approved respirators other than gas.
- 11.2-1 Approved gas masks.
- 11.2-2 Selection, fit, use, and maintenance of approved respirators.
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- 11.10 Application procedures.
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- 11.20 Examination, inspection, and testing of complete respirator assemblies; fees.
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- 11.65 Conduct of examinations, inspections, and tests by MESA and the Institute; assistance by applicant; observers; recorded data; public demonstrations.
- 11.66 Withdrawal of applications; refund of fees.

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- 11.70 Self-contained breathing apparatus; description.
- 11.71 Self-contained breathing apparatus; required components.
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- 11.75 Half-mask facepieces, full facepieces, mouthpieces; fit; minimum requirements.
- 11.76 Facepieces; eyepieces; minimum requirements.
- 11.77 Inhalation and exhalation valves; minimum requirements.
- 11.78 Head harnesses; minimum requirements.
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- 11.85-2 Compressed gas filters; minimum requirements.
- 11.85-3 Breathing bag test
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- 11.85-5 Breathing resistance test; inhalation.
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- 11.85-7 Exhalation valve leakage test.
- 11.85-8 Gas flow test; open-circuit apparatus.
- 11.85-9 Gas flow test; closed-circuit apparatus.
- 11.85-10 Service time test; open-circuit apparatus.
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- 11.85-12 Test for carbon dioxide in inspired gas; open- and closed-circuit apparatus; maximum allowable limits.
- 11.85-13 Tests during low temperature operation.
- 11.85-14 Man tests; testing conditions; general requirements.
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- 11.93 Canisters and cartridges; color and markings; requirements.
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- 11.95 Breathing tubes; minimum requirements.
- 11.96 Harnesses; installation and construction; minimum requirements.
- 11.97 Gas mask containers; minimum requirements.
- 11.98 Half-mask facepieces, full facepieces, and mouthpieces; fit; minimum requirements.
- 11.99 Facepieces; eyepieces; minimum requirements.
- 11.100 Inhalation and exhalation valves; minimum requirements.
- 11.101 Head harnesses; minimum requirements.
- 11.102 Gas masks; performance requirements; general.
- 11.102-1 Breathing resistance test; minimum requirements.
- 11.102-2 Exhalation valve leakage test.
- 11.102-3 Facepiece tests; minimum requirements.
- 11.102-4 Dust, fume, mist, and smoke tests; canisters containing filters; minimum requirements.
- 11.102-5 Canister bench tests; minimum requirements.

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- 11.110 Supplied-air respirators; description.
- 11.111 Supplied-air respirators; required components.
- 11.112 Breathing tubes; minimum requirements.
- 11.113 Harnesses; installation and construction; minimum requirements.
- 11.114 Respirator containers; minimum requirements.
- 11.115 Half-mask facepieces, full facepieces, hoods, and helmets; fit; minimum requirements.
- 11.116 Facepieces, hoods, and helmets; eyepieces; minimum requirements.
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- 11.118 Head harnesses, minimum requirements.
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 - 11.124-3 Method of measuring the power and torque required to operate blowers.
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 - 11.124-7 Air-supply line tests; minimum requirements.
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 - 11.124-13 Airflow resistance test; Type C supplied-air respirator, demand class; minimum requirements.
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 - 11.124-15 Exhalation valve leakage test.
 - 11.124-16 Man tests for gases and vapors; supplied-air respirators; general performance requirements.
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 - 11.124-18 Man tests for gases and vapors; Type B and Type BE respirators; test requirements.
 - 11.124-19 Man test for gases and vapors; Type C respirators, continuous-flow class and Type CE supplied-air respirators; test requirements.
 - 11.124-20 Man test for gases and vapors; Type C supplied-air respirators, demand and pressure-demand classes; test requirements.
 - 11.124-21 Tests for protection during abrasive blasting; Type AE, Type BE, and Type CE supplied-air respirators; general performance requirements.

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- 11.124-22 Test for protection during abrasive blasting; Type AE supplied-air respirator; test requirements.
- 11.124-23 Test for protection during abrasive blasting; Type BE supplied-air respirator; test requirements.
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- 11.130 Dust, fume, and mist respirators; description.
- 11.131 Dust, fume and mist respirators; required components.
- 11.132 Breathing tubes; minimum requirements.
- 11.133 Harnesses; installation and construction; minimum requirements.
- 11.134 Respirator containers; minimum requirements.
- 11.135 Half-mask facepieces, full facepieces, hoods, helmets, and mouthpieces; fit; minimum requirements.
- 11.136 Facepieces, hoods and helmets; eyepieces; minimum requirements.
- 11.137 Inhalation and exhalation valves; minimum requirements.
- 11.138 Head harnesses; minimum requirements.
- 11.139 Air velocity and noise levels; hoods and helmets; minimum requirements.
- 11.140 Dust, fume, and mist respirators; performance requirements; general.
- 11.140-1 Isoamyl acetate tightness test; dust, fume, and mist respirators designed for respiratory protection against fumes of various metals having an air contamination level not less than 0.05 milligram per cubic meter; minimum requirements.
- 11.140-2 Isoamyl acetate tightness test; respirators designed for respiratory protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter, or against radionuclides; minimum requirements.
- 11.140-3 Air-purifying filter tests; performance requirements; general.
- 11.140-4 Silica dust test; single-use or reusable filters; minimum requirements.
- 11.140-5 Silica dust test; single-use dust respirators; minimum requirements.
- 11.140-6 Lead fume test; minimum requirements.
- 11.140-7 Silica mist test; minimum requirements.
- 11.140-8 Tests for respirators designed for respiratory protection against more than one type of dispersoid; minimum requirements.
- 11.140-9 Airflow resistance tests; all dust, fume, and mist respirators; minimum requirements.
- 11.140-10 Exhalation valve leakage test; minimum requirement.
- 11.140-11 DOP filter test; respirators designed as respiratory protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter and against radionuclides; minimum requirements.
- 11.140-12 Silica dust loading test; respirators designed as protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter and against radionuclides; minimum requirements.

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- 11.150 Chemical cartridge respirators; description.
- 11.151 Chemical cartridge respirators; required components.
- 11.152 Cartridges in parallel; resistance requirements.
- 11.153 Cartridges; color and markings; requirements.
- 11.154 Filters used with chemical cartridges; location; replacement.
- 11.155 Breathing tubes; minimum requirements.
- 11.156 Harnesses; installation and construction; minimum requirements.
- 11.157 Respirator containers; minimum requirements.
- 11.158 Half-mask facepieces, full facepieces, mouthpieces, hoods, and helmets; fit; minimum requirements.
- 11.158-1 Facepieces, hoods, and helmets; eyepieces; minimum requirements.
- 11.159 Inhalation and exhalation valves; minimum requirements.
- 11.160 Head harnesses; minimum requirements.
- 11.161 Air velocity and noise levels; hoods and helmets; minimum requirements.
- 11.162 Chemical cartridge respirators; performance requirements; general.
- 11.162-1 Breathing resistance test; minimum requirements.
- 11.162-2 Exhalation valve leakage test; minimum requirements.
- 11.162-3 Facepiece test; minimum requirements.
- 11.162-4 Lacquer and enamel mist tests; respirators with filters; minimum requirements; general.
- 11.162-5 Lacquer mist test; minimum requirements.
- 11.162-6 Enamel mist test; minimum requirements.
- 11.162-7 Dust, fume, and mist tests; respirators with filters; minimum requirements; general.
- 11.162-8 Bench tests; gas and vapor tests; minimum requirements; general.

Subpart M--Pesticide Respirators

- 11.170 Pesticide respirators; description.
- 11.171 Pesticide respirators; required components.
- 11.172 Canisters and cartridges in parallel; resistance requirements.
- 11.173 Canisters and cartridges; color and markings; requirements.
- 11.174 Filters used with canisters and cartridges; location; requirements.
- 11.175 Breathing tubes; minimum requirements.
- 11.176 Harnesses; installation and construction; minimum requirements.
- 11.177 Respirator containers; minimum requirements.
- 11.178 Half-mask facepieces, full facepieces, hoods and helmets, and mouthpieces; fit; minimum requirements.
- 11.179 Facepieces, hoods and helmets; eyepieces; minimum requirements.
- 11.180 Inhalation and exhalation valves; minimum requirements.
- 11.181 Head harnesses; minimum requirements.
- 11.182 Air velocity and noise levels; hoods and helmets; minimum requirements.

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- 11.183 Pesticide respirators; performance requirements; general.
- 11.183-1 Breathing resistance test; minimum requirements.
- 11.183-2 Exhalation valve leakage test; minimum requirements.
- 11.183-3 Facepiece test; minimum requirements.
- 11.183-4 Silica dust test; minimum requirements.
- 11.183-5 Lead fume test; minimum requirements.
- 11.183-6 Dioctyl-phthalate test; minimum requirements.
- 11.183-7 Bench tests; minimum requirements.

Subpart N--Special Use Respirators

- 11.200 Vinyl chloride respirators; description.
- 11.201 Required components.
- 11.202 Gas masks; requirements and tests.
- 11.203 Chemical-cartridge respirators; requirements and tests.
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- 11.205 Requirements for end-of-service-life indicator.
- 11.206 Quality control requirements.
- 11.207 Labeling requirements.
- 11.208 Fees

AUTHORITY: Secs. 202(h), 204, and 508, 83 Stat. 763, 764 and 803; 30 U.S.C. 842(h), 844 and 957; secs. 2, 3, and 5, 36 Stat. 370, as amended 37 Stat. 681; 30 U.S.C. 3, 5, and 7; sec. 8(g), 84 Stat. 1600; 29 U.S.C. 657(g).

SOURCE: 37 FR 6244, Mar. 25, 1972, unless otherwise noted.

NOTE: Nomenclature changes appear at 39 FR 39039, Nov. 5, 1974.

APPENDIX IV

Code of Federal Regulations for Respiratory Protection

Chapter XVII

Occupational Safety and Health Administration

Title 29--Labor

Revised July 1977

§ 1910.134 RESPIRATORY PROTECTION.

(a) Permissible practice. (1) In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements.

(2) Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee. The employer shall provide the respirators which are applicable and suitable for the purpose intended. The employer shall be responsible for the establishment and maintenance of a respiratory protective program which shall include the requirements outlined in paragraph (b) of this section.

(3) The employee shall use the provided respiratory protection in accordance with instructions and training received.

(b) Requirements for a minimal acceptable program. (1) Written standard operating procedures governing the selection and use of respirators shall be established.

(2) Respirators shall be selected on the basis of hazards to which the worker is exposed.

(3) The user shall be instructed and trained in the proper use of respirators and their limitations.

(4) Where practicable, the respirators should be assigned to individual workers for their exclusive use.

(5) Respirators shall be regularly cleaned and disinfected. Those issued for the exclusive use of one worker should be cleaned after each day's use, or more often if necessary. Those used by more than one worker shall be thoroughly cleaned and disinfected after each use.

(6) Respirators shall be stored in a convenient, clean, and sanitary location.

(7) Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced. Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use.

(8) Appropriate surveillance of work area conditions and degree of employee exposure or stress shall be maintained.

(9) There shall be regular inspection and evaluation to determine the continued effectiveness of the program.

(10) Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The local physician shall determine what health and physical conditions are pertinent. The respirator user's medical status should be reviewed periodically (for instance, annually).

(11) Approved or accepted respirators shall be used when they are available. The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is designed in accordance with standards established by competent authorities. The U.S. Department of Interior, Bureau of Mines, and the U.S. Department of Agriculture are recognized as such authorities. Although respirators listed by the U.S. Department of Agriculture continue to be acceptable for protection against specified pesticides the U.S. Department of the Interior, Bureau of Mines, is the agency now responsible for testing and approving pesticide respirators.

(c) Selection of respirators. Proper selection of respirators shall be made according to the guidance of American National Standard Practices for Respiratory Protection Z88.2-1969.

(d) Air quality. (1) Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity. Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen. Breathing air shall meet at least the requirements of the specification for Grade D breathing air as described in Compressed Gas Association Commodity Specification G-7.1-1966. Compressed oxygen shall not be used in supplied-air respirators or in open circuit self-contained breathing apparatus that have previously used compressed air. Oxygen must never be used with air line respirators.

(2) Breathing air may be supplied to respirators from cylinders or air compressors.

(i) Cylinders shall be tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR Part 178).

(ii) The compressor for supplying air shall be equipped with necessary safety and standby devices. A breathing air-type compressor shall be used. Compressors shall be constructed and situated so as to avoid entry of contaminated air into the system and suitable in-line air purifying sorbent beds and filters installed to further assure breathing air quality. A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure, and alarms to indicate compressor failure and overheating shall be installed in the system. If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm or both. If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications in paragraph (d)(1) of this section.

(3) Air line couplings shall be incompatible with outlets for other gas systems to prevent inadvertent servicing of air line respirators with nonrespirable gases or oxygen.

(4) Breathing gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, Z48.1-1954; Federal Specification BB-A-1034a, June 21, 1968, Air, Compressed for Breathing Purposes; or Interim Federal Specification GG-B-00675b, April 27, 1965, Breathing Apparatus, Self-Contained.

(e) Use of respirators. (1) Standard procedures shall be developed for respirator use. These should include all information and guidance necessary for their proper selection, use, and care. Possible emergency and routine uses of respirators should be anticipated and planned for.

(2) The correct respirator shall be specified for each job. The respirator type is usually specified in the work procedures by a qualified individual supervising the respiratory protective program. The individual issuing them shall be adequately instructed to insure that the correct respirator is issued. Each respirator permanently assigned to an individual should be durably marked to indicate to whom it was assigned. This mark shall not affect the respirator performance in any way. The date of issuance should be recorded.

(3) Written procedures shall be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies. Personnel shall be familiar with these procedures and the available respirators.

(i) In areas where the wearer, with failure of the respirator, could be overcome by a toxic or oxygen-deficient atmosphere, at least one additional man shall be present. Communications (visual, voice, or signal line) shall be maintained between both or all individuals present. Planning shall be such that one individual will be unaffected by any likely incident and have the proper rescue equipment to be able to assist the other(s) in case of emergency.

(ii) When self-contained breathing apparatus or hose masks with blowers are used in atmospheres immediately dangerous to life or health, standby men must be present with suitable rescue equipment.

(iii) Persons using air line respirators in atmospheres immediately hazardous to life or health shall be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres or other and equivalent provisions for the rescue of persons from hazardous atmospheres shall be used. A standby man or men with suitable self-contained breathing apparatus shall be at the nearest fresh air base for emergency rescue.

(4) Respiratory protection is no better than the respirator in use, even though it is worn conscientiously. Frequent random inspections shall be conducted by a qualified individual to assure that respirators are properly selected, used, cleaned, and maintained.

(5) For safe use of any respirator, it is essential that the user be properly instructed in its selection, use, and maintenance. Both supervisors and workers shall be so instructed by competent persons. Training shall

provide the men an opportunity to handle the respirator, have it fitted properly, test its face-piece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere.

(i) Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly. Respirators shall not be worn when conditions prevent a good face seal. Such conditions may be a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses. Also, the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors shall be evaluated by periodic check. To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator. This may be done by following the manufacturer's facepiece fitting instructions.

(ii) Providing respiratory protection for individuals wearing corrective glasses is a serious problem. A proper seal cannot be established if the temple bars of eye glasses extend through the sealing edge of the full facepiece. As a temporary measure, glasses with short temple bars or without temple bars may be taped to the wearer's head. Wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed. Systems have been developed for mounting corrective lenses inside full facepieces. When a workman must wear corrective lenses as part of the facepiece, the facepiece and lenses shall be fitted by qualified individuals to provide good vision, comfort, and a gas-tight seal.

(iii) If corrective spectacles or goggles are required, they shall be worn so as not to affect the fit of the facepiece. Proper selection of equipment will minimize or avoid this problem.

(f) Maintenance and care of respirators. (1) A program for maintenance and care of respirators shall be adjusted to the type of plant, working conditions, and hazards involved, and shall include the following basic services:

- (i) Inspection for defects (including a leak check),
- (ii) Cleaning and disinfecting,
- (iii) Repair,
- (iv) Storage

Equipment shall be properly maintained to retain its original effectiveness.

(2) (i) All respirators shall be inspected routinely before and after each use. A respirator that is not routinely used but is kept ready for emergency use shall be inspected after each use and at least monthly to assure that it is in satisfactory working condition.

(ii) Self-contained breathing apparatus shall be inspected monthly. Air and oxygen cylinders shall be fully charged according to the manufacturer's instructions. It shall be determined that the regulator and warning

devices function properly.

(iii) Respirator inspection shall include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tube, and canisters. Rubber or elastomer parts shall be inspected for pliability and signs of deterioration. Stretching and manipulating rubber or elastomer parts with a massaging action will keep them pliable and flexible and prevent them from taking a set during storage.

(iv) A record shall be kept of inspection dates and findings for respirators maintained for emergency use.

(3) Routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided for the wearer. Each worker should be briefed on the cleaning procedure and be assured that he will always receive a clean and disinfected respirator. Such assurances are of greatest significance when respirators are not individually assigned to workers. Respirators maintained for emergency use shall be cleaned and disinfected after each use.

(4) Replacement or repairs shall be done only by experienced persons with parts designed for the respirator. No attempt shall be made to replace components or to make adjustment or repairs beyond the manufacturer's recommendations. Reducing or admission valves or regulators shall be returned to the manufacturer or to a trained technician for adjustment or repair.

(5) (i) After inspection, cleaning, and necessary repair, respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators placed at stations and work areas for emergency use should be quickly accessible at all times and should be stored in compartments built for the purpose. The compartments should be clearly marked. Routinely used respirators, such as dust respirators, may be placed in plastic bags. Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons.

(ii) Respirators should be packed or stored so that the facepiece and exhalation valve will rest in a normal position and function will not be impaired by the elastomer setting in an abnormal position.

(iii) Instructions for proper storage of emergency respirators, such as gas masks and self-contained breathing apparatus, are found in "use and care" instructions usually mounted inside the carrying case lid.

(g) Identification of gas mask canisters. (1) The primary means of identifying a gas mask canister shall be by means of properly worded labels. The secondary means of identifying a gas mask canister shall be by a color code.

(2) All who issue or use gas masks falling within the scope of this section shall see that all gas mask canisters purchased or used by them are properly labeled and colored in accordance with these requirements before they

are placed in service and that the labels and colors are properly maintained at all times thereafter until the canisters have completely served their purpose.

(3) On each canister shall appear in bold letters the following:

(i)--

Canister for _____
(Name for atmospheric contaminant)

or

Type N Gas Mask Canister

(ii) In addition, essentially the following wording shall appear beneath the appropriate phrase on the canister label: "For respiratory protection in atmospheres containing not more than _____ percent by volume of _____."
(Name of atmospheric contaminant)

(iii) All of the markings specified above should be placed on the most conspicuous surface or surfaces of the canister.

(4) Canisters having a special high-efficiency filter for protection against radionuclides and other highly toxic particulates shall be labeled with a statement of the type and degree of protection afforded by the filter. The label shall be affixed to the neck end of, or to the gray stripe which is around and near the top of, the canister. The degree of protection shall be marked as the percent of penetration of the canister by a 0.3-micron-diameter dioctyl phthalate (DOP) smoke at a flow rate of 85 liters per minute.

(5) Each canister shall have a label warning that gas masks should be used only in atmospheres containing sufficient oxygen to support life (at least 16 percent by volume), since gas mask canisters are only designed to neutralize or remove contaminants from the air.

(6) Each gas mask canister shall be painted a distinctive color or combination of colors indicated in Table I-1. All colors used shall be such that they are clearly identifiable by the user and clearly distinguishable from one another. The color coating used shall offer a high degree of resistance to chipping, scaling, peeling, blistering, fading, and the effects of the ordinary atmospheres to which they may be exposed under normal conditions of storage and use. Appropriately colored pressure sensitive tape may be used for the stripes.

TABLE I-1

<u>Atmospheric contaminants to be protected against</u>	<u>Colors assigned*</u>
Acid gases.	White.
Hydrocyanic acid gas.	White with 1/2-inch green stripe completely around the canister near the bottom.
Chlorine gas.	White with 1/2-inch yellow stripe completely around the canister near the bottom.
Organic vapors.	Black.
Ammonia gas.	Green.
Acid gases and ammonia gas.	Green with 1/2-inch white stripe completely around the canister near the bottom.
Carbon monoxide.	Blue.
Acid gases and organic vapors.	Yellow.
Hydrocyanic acid gas and chloropicrin vapor.	Yellow with 1/2-inch blue stripe completely around the canister near the bottom.
Acid gases, organic vapors, and ammonia gases.	Brown.
Radioactive materials, excepting tritium and noble gases.	Purple (Magenta).
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors.	Canister color for contaminant, as designated above, with 1/2-inch gray stripe completely around the canister near the top.
All of the above atmospheric contaminants.	Red with 1/2-inch gray stripe completely around the canister near the top.

* Gray shall not be assigned as the main color for a canister designed to remove acids or vapors.

NOTE: Orange shall be used as a complete body, or stripe color to represent gases not included in this table. The user will need to refer to the canister label to determine the degree of protection the canister will afford.

APPENDIX V

Criteria for a Recommended Standard...
Occupational Exposure to Benzene

U.S. Department of Health, Education, and Welfare
1974

BIOLOGIC METHOD FOR SAMPLING AND ANALYSIS OF BENZENE

The recommended biologic method for urinalysis is derived from Sherwood and Carter. [102] It has been designed to determine the concentration of phenol and its conjugates, sulfate and glucuronide, in urine. It also determines orthocresol and meta- and paracresols. Urine is hydrolyzed with perchloric acid at 95 C, and the phenols and cresols are extracted with isopropyl ether and determined by gas chromatography.

Collection of Urine Samples

"Spot" urine specimens of about 100 ml are collected as close to the end of the working day as possible. If any worker's urine phenol level exceeds 75 mg/liter, procedures are instituted immediately to determine the cause of the elevated urine phenol levels and to reduce benzene exposure to the worker. Weekly specimens are collected as described above until 3 consecutive weekly determinations indicate that urinary phenol levels are below 75 mg/liter.

After thoroughly washing their hands with soap and water, workers shall collect urine samples from single voidings in clean, dry specimen containers having tight closures and at least a 120-ml capacity. Collection containers may be glass, waxcoated paper, or other disposable types if desired. Following collection of urine specimens, 1 ml of a 10% copper sulfate solution is added to each sample as a preservative, and samples are immediately stored under refrigeration, preferably at 0-4 C.

Refrigerated specimens will remain stable for approximately 90 days. If shipment of samples is necessary to perform analyses, the most rapid method available shall be employed utilizing acceptable packing procedures as specified by the carrier. Proper identification of each specimen shall include as a minimum, the worker's name, date, and time of collection.

Analytical

(a) Principle of the Method

Urine samples are treated with perchloric acid at 95 C to hydrolyze the phenol conjugates, phenyl sulfate, and phenyl glucuronide, formed as detoxification products following benzene absorption. The total phenol is extracted with diisopropyl ether and the phenol concentration is determined by gas chromatography analysis of the diisopropyl ether extract.

(b) Apparatus

(1) Gas chromatograph with a flame ionization detector and equipped with a 5-foot x 3/16-inch column packed with 2 w/w polyethylene glycol adipate on universal 'B' support. Operating conditions are as follows:

Column temperature	150 C
Detector temperature	200 C
Injection port temperature	200 C
Carrier gas	Nitrogen
Carrier gas flowrate	60 ml/min

(2) Water bath

(3) Glass-stoppered, 10-ml volumetric flasks

(4) . 1-ml, 2-ml, and 5-ml volumetric pipets

(5) . 5- μ l syringe

(c) Reagents

(1) Phenol

(2) Perchloric acid

(3) Diisopropyl ether

(4) Distilled water

(d) Procedure

(1) Hydrolysis of Phenol Conjugates

Pipet 5 ml of urine into a 10-ml, glass-stoppered, volumetric flask. Add perchloric acid, mix by swirling, and transfer the lightly stoppered flask to a water bath at 95 C. After 2 hours, remove the flask from the water bath and allow to cool at room temperature.

(2) Diisopropyl ether extraction of phenol and cresols.

Pipet 1 ml of diisopropyl ether into the flask and adjust the volume to 10 ml with distilled water. Shake vigorously for 1 minute to extract the phenol and cresols. Allow the aqueous and ether layers to separate.

(3) Gas chromatographic analysis for phenol

Inject 5 μ l of the diisopropyl ether layer into the gas chromatograph and record the attenuation and area of the phenol peak. Under the conditions described, phenol is eluted in 100 seconds, orthocresol in 130 seconds, and meta- and paracresols in 320 seconds.

(e) Standards Preparation

A 50 mg/liter standard aqueous solution of phenol is prepared. A 5-ml aliquot of the standard solution is then subjected to the hydrolysis, extraction, and gas chromatographic analysis procedures described under Procedure above.

(f) Calculations

Determine the phenol concentration in the urine by comparing the gas chromatographic peak area of the sample with that of the 50 mg/liter standard and adjust the value to a specific gravity of 1.024.

(g) Specific Gravity Correction

Due to the magnitude of correction which is required, samples having uncorrected specific gravities less than 1.010 shall be rejected and another sample shall be obtained.

Based on a survey of a large population in the United States in connection with urinary lead excretion, Levine and Fahy [139] found the mean specific gravity to be 1.024. Many investigators throughout the world now use this figure. Buchwald [130] in 1964 determined the mean specific gravity for residents in the United Kingdom to be 1.016, a value now frequently used for Northern Europeans. The importance of specific gravity adjustments can be seen in that a specific gravity of 1.016 will give results having two-thirds the value of those corrected to 1.024. It is important, therefore, that a value be chosen for standardization; since greater acceptance seems to be for 1.024, this value has been selected for adjustment of urinary concentrations of benzene recommended for biological monitoring.

$$\text{corrected concentration} = \frac{\text{observed concentration} \times 24}{\text{last 2 digits of sp gr (eg, 1.021)}}$$

**UPDATE CRITERIA AND RECOMMENDATIONS FOR A
REVISED BENZENE STANDARD AUGUST 1976**

In 1974, the National Institute for Occupational Safety and Health (NIOSH) issued criteria and recommendations for a standard for occupational exposure to benzene [1]. A cause-and-effect relationship between benzene and observed blood abnormalities, especially aplastic anemia, was recognized. At that time, NIOSH, recognizing that there were data suggesting a relationship between exposure to benzene and the occurrence of leukemia among employees at risk of such exposure, expressed its need for detailed comprehensive epidemiologic investigations of the long-term relationships of morbidity and mortality due to leukemia and other malignancies in the population at large and in those who work with benzene.

Between 1974 and mid-1976, seven epidemiologic studies have been reported [2-8] along with case reports of benzene-related blood dyscrasias [9-11] and chromosomal aberrations [11-14]. Although some investigators have observed only acute forms of benzene-associated leukemias [9-12], a recent connection with chronic leukemias has been noted [3,4,13]. Reports prior to 1974 of chronic myelocytic or lymphocytic leukemia [15-18] and erythroleukemia [19-23] are not as numerous as the observations of acute myelocytic or lymphocytic types [16,17,24-26]. Because of the rarity of erythroleukemia, Vigliani and Forni [12] regard as significant the three cases which they have observed. Because case records accumulated by one investigative group [12] of patients with acute or subacute leukemia have become so numerous in the past two decades, many cases formerly diagnosed as acute pancytopenia are now considered to be examples of acute leukemia.

In 1974, McMichael et al [3] reported on the first phase of a study of a population at risk comprised of active and retired employees

of a major tire-manufacturing plant in Akron, Ohio. A cohort of 6,678 male rubber workers was followed for 9 years (1964 through 1972), and data on 1,783 deaths were obtained. Comparison with the 1968 US national mortality data yielded a Standardized Mortality Ratio (SMR) in the U.S. male population of 99 from all causes of death for the full cohort and of 93 for an active employment subcohort in the age range of 40 to 64. Among other findings of cause-specific deaths, the highest SMR's were for deaths from causes related to the hematopoietic and lymphatic systems. The SMR showed an excess mortality of approximately 2-2.5 and was higher for the "active" age range (40-64) than for the full age range (40-84). For leukemia deaths in the 40-64 age range, the SMR was 315—approximately a threefold excess. It was recognized that, because no distinction was made in this evaluation between different groups of workers having different work experiences, a "dilution effect" could occur. A second phase of the study [4,6] compared different groups of rubber workers. McMichael et al [3] stated that, from this initial study alone, it should not be assumed that the observed cause-specific mortality excesses were attributable to work-environment exposure within the rubber industry. Such excesses could have been a spurious association such as a "selected" population in which all persons living in Akron might have been exposed to some specific unknown factor. Similar findings from 5 other plants in widely differing parts of the US, however, make this explanation unlikely, in the opinion of the authors. Pending completion of the second phase of the study, the authors concluded that they could only suspect, rather than conclude with confidence, that working in certain jobs within the rubber industry entails an increased risk of dying from these specific causes.

In a followup of the same cohort [3], Mc-

Michael et al [4] in 1975 extended the epidemiologic study to indicate an association between leukemia and jobs entailing exposure to solvents among which benzene was once the solvent of choice. After noting that leukemias in general demonstrated a threefold excess in mortality in the 40-64 age range, and with further subclassification of the International Classification of Diseases categories to identify specific leukemias, a sevenfold excess of deaths from lymphatic leukemia in the 40-64 age range was observed. Six of eight deaths were from chronic lymphatic leukemia. Myeloid leukemia was the next highest category in this age range, showing a twofold excess. At smaller plants not located in Akron, Ohio, a complete study was not performed for reasons of cost and time; nevertheless, a proportional mortality analysis demonstrated a 45% excess of leukemia. The question of whether the observed mortality excesses were associated with specific job categories within the rubber industry was then investigated. Nineteen of 70 occupational titles were associated with solvent exposure and were grouped as heavy, medium, and light solvent exposure. A discriminant function analysis based on time spent in various work groups and independent of the previously observed mortality excess revealed a statistically significant positive association between solvent exposure and lymphatic leukemia. One job title within the 3 solvent-exposure groups, tire repair, showed a sixfold difference between cases and controls in a comparative test of relative risk of lymphatic leukemia. It was pointed out that tire repair involves considerable swabbing of tires with solvent, and, at some time in the past, the solvent predominantly used was benzene. Because each of the 4 cases observed had started working at the plant at some time since 1945, it was suggested that the leukemogenic agent may be a chemical that had been present in recent decades and may still be present. Finally, it was of interest to the authors [4] that it was lymphatic rather than myeloid leukemia that appeared to be associated with solvent-exposure jobs.

A third study by McMichael et al [6] in 1976 involving the same cohort of rubber workers previously reported [3,4] indicated

that mortality from lymphatic leukemia was also very strongly associated with working in the synthetic plant, a place where NIOSH has been unable to identify benzene-related exposures. The synthetic plant is essentially a chemical plant making important synthetic-rubber intermediate products, such as styrene-butadiene and neoprene. An unexpected association of lymphatic leukemia with the janitoring-trucking occupational title group was explained by speculating that the transfer of workers to this group occurred for medical reasons, especially where conditions were not rapidly fatal and for which active employment could be maintained while in apparent disease remission or stabilization. Andjelkovic et al [5], studying the same cohort as McMichael et al [3,4,6], distinguished between active worker mortality experience and retired worker mortality experience, particularly in workers who retired before age 65. Results were essentially the same as previously reported [3,4,6] with findings of excess mortality for both active and retired workers from neoplasms of the lymphatic and hematopoietic tissues. In addition, the expectation was confirmed that workers who retired prior to the normal retirement age of 65 would have a less favorable mortality [experience] than active workers of the same age range; however, the magnitude of the excess, an SMR of 202 as compared with 61 for the active workers, was unexpected (p less than 0.001).

Monson and Nakano [7] in 1976 reported another mortality study in a cohort of 13,571 white male rubber workers, again in Akron, Ohio. From the records of 5,079 deceased employees, excess deaths from leukemia occurred most often among workers in the tire (18 observed/11.7 expected) and in the processing (10/4.2) divisions. Excesses were also seen among workers in the chemical division (2/0.7), in elevator areas and cleaning (3/0.4), in shops (7/6.6), and in industrial products (9/7.0). Benzene was reported to have been used extensively in the industry. While pure benzene was no longer used as a solvent, it was stated to be a contaminant in many of the solvents still used [7].

In a mortality study of 20,163 petroleum-

refinery workers carried out in 17 refineries [8], mortality from lymphomas was reported to be greater than expected, though not statistically significant, in 3 categorized exposure groups listed as high exposure (laboratory, maintenance, and salvage-recovery jobs), low exposure (plant security, utility, purchasing, and motor transport jobs), and medium exposure (all other jobs). A suggestion was made of increased mortality with increased exposure. No mention was made of benzene exposure. In an epidemiologic survey of leukemia reported by Thorpe [2] in workers in a variety of petroleum and petrochemical operations, a number of problems of data collection were experienced. The incidence of benzene-associated leukemia was not considered to be abnormal compared to that of the general population in the countries concerned. Emphasis was placed on the need for improvement in the recording and storage of biologic observations, job histories, occupational exposures, and demographic data.

A 1971 report by Ishimaru et al [27] deserves to be mentioned here because it specifically associates benzene or its derivatives and medical X-rays with an approximately 2.5 times excess risk of leukemia in workers. Ishimaru et al [27] organized 15 groupings based on occupational categories reportedly listed by Milby et al [28] as workers who handle benzene or are exposed to medical X-rays. Four categories were not included in the reported results because the authors found no leukemia in either test or control workers with such occupational histories as lithographers, painters, and laboratory technicians; yet, these workers might well be expected to experience benzene exposure because of the known presence of benzene in such occupations. Many of the selected occupations such as carbon dioxide-gas furnace workers, tinsmiths, sheetmetal workers, soft drink-manufacturing workers, and barbers were not listed by Milby et al; furthermore, those occupations would not likely have benzene exposure. In addition, no investigation was made of the specific chemical agents handled by the individuals engaged in the selected occupations and the identified cases of leukemia in both the test and the control groups were generally

low, mostly numbering only 1 or 2. Occupations where a high association with benzene exposure would be expected, such as leather products workers and workers engaged in printing, repairing, or cleaning of printing machines, showed no excess whereas welders, platers, tinsmiths, or sheetmetal workers demonstrated an excess of leukemia where extensive use of benzene would be questionable. This study [27] is not considered to be sufficiently definitive to conclude that a relative risk of leukemia from probable occupational exposure to benzene or its derivatives exists.

Animal experiments designed to investigate the carcinogenic action of benzene have failed to give reliable information on its capacity to produce an increased incidence of leukemias [29]. Lignac [30] in 1932 claimed to have produced six cases of leukemia and two cases of lymphosarcoma in a strain of white mice given 0.001 ml benzene in olive oil once a week by subcutaneous injection for up to 11 months. Attempts to repeat these observations have yielded equivocal results [31-34]. A high tumor incidence often manifested as leukemias in untreated mice has been found to be caused by certain virus strains. It has therefore been considered quite conceivable that leukemias described in the earlier experiments in mice after benzene treatment have, in large part, developed spontaneously or by virus infection, rather than being caused by benzene [29].

The literature is replete with medical case reports of leukemia directly associated with occupational exposure to benzene. These leukemias have occurred throughout the industrial world, most frequently as a result of using benzene in solvent applications. In France, Goguel et al [17] in 1967 described 50 instances of leukemia, of which six had already been reported, in the Paris region from 1950 to 1965. The 44 new cases included 13 chronic myelocytic leukemias, 8 chronic lymphocytic leukemias, and 23 acute leukemias. Frequent disturbances of the erythrocytes and their precursors were noted. Girard and Revol [16] added four observations of acute myeloid leukemia and nine cases of chronic lymphocytic leukemia in 1970. In the Soviet Union,

Tareeff et al [18] found 6 acute and 10 chronic cases of leukemia among what were described as printers, primers, apparatus men, and chemists. In papers published mostly through the 1970's, Aksoy and coworkers [9,10,24, 35-39] in Turkey have identified more than 50 patients with aplastic anemia and 34 cases of leukemia, all in workers having chronic exposure to benzene. These included one case of erythrocytic leukemia, three cases having a possible genetic predisposition, and one case of chronic myelocytic leukemia. In addition, a suggested relationship between Hodgkin's disease and chronic benzene exposure was reported. In Italy, 34 fatal cases of benzene-associated aplastic anemia and leukemia have been observed [12]. Data from the Institute of Occupational Health of Pavia, Italy, indicate that, of 16 deaths occurring between 1960 and 1974 among 142 workers identified with chronic benzene poisoning, only 3 died of aplastic anemia and 13 died of leukemia [12]. The observations of at least 20 cases of acute erythroleukemia in the literature is considered to be significant [12] because of the rarity of the disease. Vigliani and Saita [40] in 1964 calculated that, for workers heavily exposed to benzene in the provinces of Milan and Pavia, the risk of acute leukemia was at least 20 times that of the general adult population. Cases of benzene-associated leukemia have also been reported in Spain [20], Scandinavia [22], and the United States [13,25].

The consistent observations of chromosomal aberrations associated with benzene exposure continue to be reported [13,41,42]. The implications of the chromosome findings with respect to benzene leukemia are still not clear. The possibility of a chromosomal instability acting as a stimulus for a latent leukemogenic virus has been speculated upon [12].

The recently reported isolation of a complete human RNA tumor virus (Type C) associated with acute myelocytic leukemia [43,44] raises again the possibility that a chemical carcinogen activates a latent leukemogenic virus in accord with the generalized suggestion of Todaro and Huebner [45]. The demonstration of a relation between exposure to ben-

zene, the appearance of a virus in exposed human beings, and the occurrence of acute leukemia in these people would strongly support such a hypothesis.

It is apparent from the literature that so-called benzene leukemia continues to be reported. The inadequacies in correlating exposure-effect relationships were discussed by NIOSH in 1974 [1] and studies subsequent to 1974 which would aid in evaluating the consequences of exposures to various airborne concentrations of benzene have not been found in the literature. Case records of patients with acute or subacute leukemia have become so numerous that, according to Vigliani and Forni [12], they exceed those of acute pancytopenia, a fact which has led to the belief that many cases previously considered as pancytopenia may indeed have been examples of hemocytoblastic leukopenic and aleukemic leukemia. In spite of the diversity of chemicals to which workers are frequently exposed, both singly and in mixtures, the development of blood abnormalities can, for the most part, be linked with exposures to benzene. Data are lacking to support the suggestion by Girard and Revol [16] that homologues of benzene might be leukemogenic. Vigliani and Forni [12] observed that since the replacement of benzene with toluene as a solvent in the rotogravure industry in 1964, no new cases of aplastic anemia or of leukemia due to toluene exposure have been seen. Furthermore, workers have not shown the chromosome aberrations frequently seen in workers exposed to benzene. The statement by Gerarde [46] that benzene is unique among hydrocarbons in its myelotoxic potency seems as valid today as in 1960 when it was made. The excess risk of leukemia recently reported in the rubber industry by separate investigative groups [3-7] is considered by NIOSH to be indicative of probable benzene exposure, especially since benzene was at one time the agent of choice for many solvent operations.

NIOSH considers the accumulated evidence from clinical as well as from epidemiologic data to be conclusive at this time that benzene is leukemogenic. Because it causes progressive, malignant disease of the blood-

forming organs, NIOSH recommends that, for regulatory purposes, benzene be considered carcinogenic in man. In view of this conclusion and since it is not possible at this time to establish an exposure level at which benzene may be regarded to be without danger, NIOSH recommends that exposure to benzene be kept as low as possible. The use of benzene as a solvent or diluent in open operations should be prohibited. Furthermore, product substitution should be a paramount consideration. Wherever benzene is identified or its presence suspected, especially with concurrent indications of alterations in the blood or the hematopoietic system, it should be replaced with less harmful substitutes wherever feasible.

The sampling and analytical method for benzene in air recommended by NIOSH [1] employs adsorption on charcoal followed by desorption and gas chromatographic measurement. Personal sampling pumps operating at approximately 1 liter/minute, for a 10-minute sample at a mean concentration of 22.8 ppm, collected a quantity of benzene that, upon analysis, yielded a relative standard deviation (precision) of 11.6% [1]. Results from collaborative testing indicate that sampling at 1 liter/minute for 2 hours will collect a sufficient quantity of benzene from an airborne concentrations of 1 ppm to allow a relative standard deviation in the range of that previously reported [1], which is considered acceptable. One ppm represents the lowest level at which a reliable estimate of occupational exposure to benzene can be determined at this time, in consideration of the limitations of biologic and air measurement techniques. NIOSH recommends that occupational exposure be controlled so that no worker will be exposed to benzene in excess of 1 ppm (3.2 mg/cubic meter) in air as determined by an air sample collected at 1 liter/minute for 2 hours.

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Revised Recommendation

for an Occupational Exposure Standard for Benzene

The National Institute for Occupational Safety and Health (NIOSH) recommended on August 25, 1976 that occupational exposure be controlled so that no worker will be exposed to benzene in excess of 1 ppm (3.2 mg m^{-3}) in air as determined by a 2-hour air sample collected at 1 liter per minute. Previously, in a criteria document transmitted July 24, 1974, to the Occupational Safety and Health Administration (OSHA) in the Department of Labor, NIOSH recommended adherence to the present Federal standard of 10 ppm as a time-weighted average with a ceiling of 25 ppm (but without the permitted excursion to 50 ppm as in the existing standard). At that time, NIOSH, recognizing that there were data suggesting a relationship between exposure to benzene and the occurrence of leukemia and other malignant diseases among employees at risk of such exposure, expressed the need for detailed, comprehensive epidemiologic investigations of the long-term relationships of morbidity and mortality due to leukemia and other malignancies in the population at large and that of workers with benzene. The recommendation for a more stringent standard was made after review of evidence subsequently accumulated from clinical as well as additional epidemiological data indicating that benzene is leukemogenic. Because it causes progressive malignant disease of the blood-forming organs, NIOSH recommends that for regulatory purposes, benzene shall be considered to be carcinogenic in man.

An issue of particular concern is the presence of benzene in gasoline and its impact, particularly in gasoline station operations. Recent information indicated that service station attendant exposures were less than 10 ppm total gasoline vapors and that if United States gasoline remain at about 1 percent by volume of benzene, exposure levels to ben-

zene will probably stay below 1 ppm. Future efforts to reduce evaporative losses at gasoline stations under EPA regulations should help to further decrease exposure to benzene at such facilities. Emphasis should be placed on prohibiting the occupational use of benzene as a solvent or diluent in open-type operations. Furthermore, product substitution should be a paramount consideration wherever benzene is identified or its presence suspected, especially with concurrent indications of alterations in the blood or the hematopoietic system, it should be replaced with less harmful substitutes wherever feasible.

Because it is not possible at present to establish a safe exposure level for a carcinogen, the NIOSH recommendation is to restrict exposure to very low levels that can still be reliably measured in the workplace. The NIOSH recommendation can be expected, at a minimum, to materially reduce the risk of benzene-induced leukemia. The recommended standard is readily measurable by techniques that are valid, reproducible, and available to industry and Government agencies.

In addition to possibly causing leukemia, exposure to benzene can result in central nervous system depression and skin irritation. Compliance with all sections of the NIOSH recommended standard should prevent noncarcinogenic adverse effects of inhalation or dermal exposure to benzene in the workplace. NIOSH estimates that 2 million workers are potentially exposed to benzene in printing, lithography, and dry cleaning, and in the manufacture of coke and gas, adhesives, coatings, and a variety of chemicals. The proposed standard would apply to the processing, manufacture, and use of benzene and benzene products covered by the Occupational Safety and Health Act.

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